Curating NASA’s Past, Present, and Future Astromaterial Sample Collections

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Overview

- Give you a general overview of the efforts involved with NASA’s astromaterials curation:
  - The Collections and the Clean Rooms...

- Other aspects of Curation
  - Clean room monitoring
  - Physical Security (incl. remote storage)
  - Physical Infrastructure
  - Data Management
  - Instrumentation
  - Shipping and receiving
  - Tours and EPO
  - Future Mission Planning and Technique Development
JSC’s Astromaterials Acquisition & Curation Office

Our Past 50 years – planning for and curating multiple collections

- **Lunar (1969)**: Apollo program lunar rocks and soils; Luna samples
- **Meteorite (1977)**: Antarctic Search for Meteorites (ANSMET) program
- **Cosmic Dust (1981)**: Cosmic dust grains from Earth’s stratosphere
- **Microparticle Impact Col. (1985)**: Space exposed hardware from spacecraft
- **Genesis (2004)**: Genesis solar wind samples at Earth-Sun L1 point
- **Stardust (2006)**: Cometary and interstellar samples from Comet Wild 2
- **Hayabusa (2012)**: Samples collected from JAXA asteroid mission to Itokawa

Our Near Future . . .

- **Hayabusa II (2020)**: Subset of samples collected from JAXA asteroid mission to (162173) 1999
- **OSIRIS-REx (2023)**: Asteroid sample return from 101955 Bennu

Our More Distant Future . . .

- **Moon (2020s)**: Non-volatile-rich farside/polar sample return
- **Comet (2020s)**: Cold curated (?) surface sample return from a comet
- **Phobos (2020s)**: 10% of a JAXA mission to bring back Phobos material
- **Mars (~2030+)**: Various Mars Sample Return

Authority from NPD 7100.10F + derivative NPR

To Protect and Serve...
The JSC Astromaterials Facility
Apollo Sample Collection 1969-1972

- The Apollo missions collected 382 kg (2200 samples) of rock, soil, and cores from 6 geologically diverse locations on the Moon.
- Only sample suite collected by astronauts, and the only suite collected with geologic context.
- Lunar lab complex is our largest suite of clean rooms and ancillary labs (ISO 6-7)
  - Clean room, storage and working areas designed to minimize contamination from the environment and other samples.
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Antarctic Meteorite Collection
1977-Present

- For 40 years, teams of scientists have collected meteorites in the Trans-Antarctic Mountains.
- Collection locations are blue ice fields where meteorites entrained in glaciers have been exposed by sublimation.
- Samples found by systematic searches of open ice fields and moraines.
- Meteorite lab complex is similar to the lunar labs (ISO 7), but only “special” meteorites are worked on in cabinets, others are processed in air.
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Cosmic Dust from the Stratosphere 1981-Present

- NASA collects atmospheric dust on collectors using high altitude reconnaissance aircraft.
- Most collections are with silicone oil collectors of random material
  - Dry collections attempts.
  - Target comet streams (Giabobini-Zinner).
- Surface collection attempts
- Clean room (ISO 5) and specialized sample handling techniques allow isolation and preservation of micron scale samples from comets, asteroids, and interstellar dust.
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Microparticle Impact Collection 1985-present

- JSC curates a variety of spacecraft and spacecraft components.
  - Surveyor III; LDEF; Solar Maximum satellite; Genesis/Stardust; and European Recoverable Carrier.
- Give the opportunity to study variety of effects: “micro-meteoroid” impacts, UV exposure, atmospheric oxygen erosion, radiation effects, etc.
- This lab also houses the coupons and witness materials for OSIRIS-REx
Genesis Solar Wind Samples 2004

- NASA mission that collected solar wind at Earth-Sun L1 location for 28 months.
  - Multiple detector arrays to sample different solar wind regimes
- Had an “off nominal” landing
  - Highlighted the importance of planning for worst case scenarios.
- Assembled and curated in JSC curation’s best clean room (ISO 4), a vertical laminar flow modular cleanroom (a retrofit lunar lab).
  - Cleaning techniques developed
- Ultimately most of the science results were achieved
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Stardust Comet + Interstellar Grains
2006

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  - Estimated that many 1000s of comet particles were collected; 100s of interstellar particles
- Particles were captured by impacts into aerogel.
- Stored in a dedicated ISO class 5 clean room.
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Hayabusa Asteroid Samples 2012

- JAXA mission to study Itokawa, an S-type asteroid (535 meters long).
- Part of the mission involved surface sample collection of small particles by firing a projectile at the surface and flying through the debris.
  - Collection mechanism didn’t quite work as intended, but thousands of particles returned in the 10-100 micron size range.
- First samples returned from an asteroid and first samples returned from an airless body not named “The Moon”
Quick Capabilities Summary

- Variety of different clean rooms (ISO 4-7), different sample storage and working conditions
  - Ultimately, the sample needs drive the lab capabilities, but cost, space, and time plays a factor
  - Colocation allows shared infrastructure and personnel

- Huge variety of sample types:
  - Large rocks, small rocks, bulk regolith, core samples, individual μm-particles, embedded μm-particles, solar wind atoms, and spacecraft parts.

- Requires a huge diversity of sample handling capabilities:
  - Processing in cabinets, processing on flow benches, band saws, wire saws, thin sections, micro-manipulation, microtome, FIB sectioning, keystoning (aerogel), etc.
Monitoring Laboratory Cleanliness

- Daily monitoring of the UPW sys.
- Weekly particle counts in labs.
- The composition of each delivery of N\textsubscript{2} is measured.
  - Delivery is refused if outside of spec.
- The O\textsubscript{2} + H\textsubscript{2}O in the lunar cabinets is measured 4x hour
  - Cycles through all cabinets.
- The isotopic composition of the N\textsubscript{2} gas is measured monthly.
- Periodically we analyze the composition of particles when the cabinets are cleaned.
- Periodically we measure the total organic hydrocarbons in the labs.
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Physical Security of the Samples

- Building is designed to protect the samples from natural disasters; also from unnatural disasters
Physical Security of the Samples
Remote Storage Facility

- Store a subset of the collection at a remote location
- Static nitrogen storage
- Requires biennial maintenance visits.
Physical Infrastructure

- The clean rooms themselves are just a part of the picture, numerous infrastructure systems must be maintained
- Stable power supply
  - Emergency backup
- HEPA-filtered HVAC air for the labs
  - We have >10 units
- Liquid/gaseous N\textsubscript{2} system
- Ultrapure water system
  - Important to integrate these
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Data Management

- Need a database to track your samples – we track >250k over the different collections.
  - Need to be able to create relationships among samples, change weights, etc.
  - Different collections have diff. needs
  - Level of accountability is key
- Other data important to the samples needs to be archived
  - >100k sample images
  - > 125 meters of shelving w/ processing notes
  - ~50,000 return sample histories
  - Countless information about geologic context, spacecraft data, or catalogs need to be included.
- Need an external website to advertise your wares.
- Data issues are going to get worse!
Shipping and Receiving

Astromaterials Allocation Numbers

- Apollo
- Meteorite
- Cosmic Dust
- Genesis
- Stardust
- Genesis Reference samples
- Hayabusa
- Hardware
- Total

Fiscal Year: FY 2001 to 2016 spring

Halfway FY 2016
EPO and Tours

- We ship out about 600 lunar and meteorite education packages a year
  - Reaches >50,000 students
- We also support numerous other EPO and PAO events
- 80 long term lunar displays
- In the past year, we did nearly 200 tours for nearly 1,000 people (just for lunar).
  - There will be tours that you just can’t say no to.
  - Important for funding.
Analytical Capabilities

- There are several different categories here:
  - In lab curation techniques – optical microscopy, FTIR
  - In Curation techniques (separate labs, but curation controlled) – Raman, XCT, XRF (future)
  - We are collocated with the JSC astromaterials research group, giving us access to advanced instrumentation
    - SEM, EPMA, SIMS, TEM, TIMS, ICPMS, FIB, FTIR, XRD
    - Used in both sample characterization and contamination knowledge/control
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The curation of samples should not begin when they arrive on Earth (though this is important).

The curation of samples should not begin while you are building the spacecraft (though this is important).

The curation of samples should begin with the initial planning and design of the mission, and be carried through every aspect of the mission.

This is the only way to ensure that you maximize the science return of your samples, particularly if something unexpected happens.
OSIRIS REx

- **Materials Coupons** – Examples of materials used in the spacecraft that are possible sources of contamination.
  - Several hundred materials in total.
  - Some analyzed now, most archived for posterity in a dedicated cabinet in an ISO 7 cleanroom.

- **Witness Plates** – High purity materials continuously exposed during spacecraft ATLO
  - Ultrapure Al-foil and Si-wafers are exposed during spacecraft assembly.
  - They are analyzed by SEM each month (while others are archived) for near real-time feedback on the contamination environment that the spacecraft is exposed to.
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Always thinking ahead and planning for the next few missions.

Active areas of curation research:
1. Precision Organic Contamination Control
2. Cold Curation
3. Next Generation Sample Handling
4. Precision Inorganic Contamination Control
5. Robotics and Next Generation Processing Techniques

By the time a mission is ready to fly we likely too late to begin the learning curve for curating the samples.
Summary

- Much more to the curation of astromaterials than simply building clean rooms.
- People are as important as the facilities:
  - Curators – one per collection
  - Processors and Technical staff
- Colocation with analytical facilities will greatly enhance curation capabilities
- Everything Takes longer (balances)
- Careful forethought is a key for future flexibility